Annual Progress Report

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Aircraft Measurements for Understanding Air-Sea Coupling and Improving Coupled Model Predictions Over the Indian Ocean

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LONG-TERM GOALS

The goals of this PI are to understand the physical processes that control the air-sea interaction and its impact on a wide rang of weather and climate systems and improve coupled atmosphere-ocean prediction through development of innovative coupled models and observations.

OBJECTIVES

The specific objectives of this study are to

- obtain coincident measurements of the lower atmosphere, air-sea interface, and the upper ocean adequate for model evaluation;
- better understand the physics of air-sea coupling and its impact on convective organization including convectively induced cold pool structure;
- examine corresponding air-sea fluxes and boundary layer recovery that affects time scales of convection;
- diagnose high-resolution coupled model such as COAMPS forecasts of convective cloud systems and convective cold pool structure to determine the effects of air-sea coupling on the convective organization in the coupled model on multi-scale convection-environment interaction, including diurnal, 2-day, and synoptic variability and their up-scaling influence in both convectively active and suppressed phases of MJO; and
- improve physical representation of the air-sea coupling processes in coupled models through airborne and satellite observations over the Indian Ocean.

The outcome of this study is expected to improve MJO prediction through a better understanding of the physical processes and a unique data set for model evaluation, verification, and potential for future coupled data assimilation, which are critical for developing a new generation, high-resolution, coupled models.

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APPROACH AND WORK PLAN

The air-sea measurements obtained using the NOAA WP-3D aircraft during the DYNAMO/LASP (Dynamics of Madden-Julian Oscillation/Littoral Air-Sea Program) field campaign from November-December 2011 will be used to address science questions related to "air-sea interaction and its impact on cloud processes in MJO." Our approach is to make aircraft measurements with flight patterns designed to address various issues on convective and air-sea coupled processes and coupled modeling. The observations collected during the field campaign will be followed by in-depth data analyses. The aircraft measurements will complement ship measurements by providing an extended coverage of the high-resolution fixed-point time series obtained from a ship. The observations will be used to evaluate the performance of high-resolution, coupled model such as COAMPS to identify error sources and guide further improvements in representing the physics of the coupling processes on various time and spatial scales.

WORK COMPLETED

During FY12-13, the research supported under the current LASP grant has focused on post-field campaign data analysis and publication of the science results. Here is a brief summary:

- Continuing satellite and GPS dropsonde data analysis in the context multi-scale interaction between convective cloud systems and large-scale environmental water vapor and synoptic circulation in the MJO initiation during the MJO2 event from November-December 2011;
- Working in collaboration with Dave Jorgensen on Doppler radar data analysis for convective missions;
- Working with NCAR/UW S-PolKa PIs and Chris Zappa on fresh water pools/SST variability, and tropospheric water vapor profile comparisons;
- P3 and Falcon aircraft data intercomparison;
- Working with aircraft and ship groups on air-sea fluxes, cold pools structure and recovery
- Participating in model intercomparison group including COAMPS
- Submission of three publications: Kerns and Chen (2013a), Kerns and Chen (2013b), Judt and Chen (2013), and
- Preparation for publications of research results on 1) aircraft observations during DYNAMO (Chen 2013a), and 2) convective cold pool structure and recovery in MJO (Chen et al. 2013b).

RESULTS

1. Multi-scale convective-environment interaction in MJO initiation

The results have been documented in two publications: Kerns and Chen (2013a, MWR) and Judt and Chen (2013). Here we show an example of Kerns and Chen (2013a) that the main conclusions can be summarized in Fig. 1 with two main points:

- Dry air intrusion re-arrange convection from ITCZ (off equator) to MJO (on equator) during the onset phase.

- Dry air intrusion associated with Rossby Gyre suppress convection on the west and favor eastward propagation of MJO.

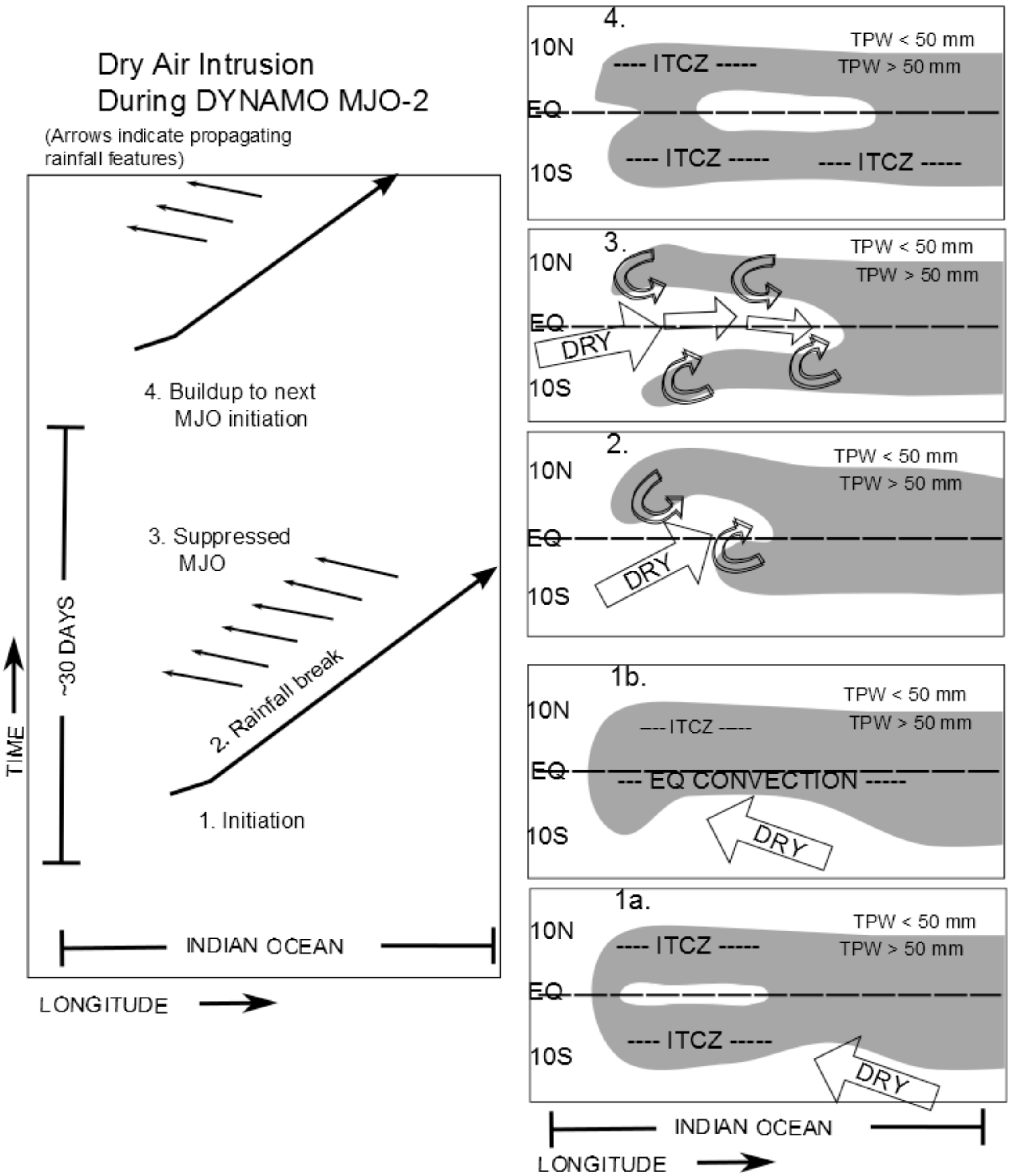

Figure 1. Schematic of the evolution of DYNAMO MJO-2 in the Indian Ocean. The left side is a time-longitude perspective. Arrows represent the propagating features with the heaviest rainfall. The right side is schematic map of the moist equatorial region (TPW > 50 mm), dry air intrusions (marked with "DRY" and box arrows), and related synoptic "Rossby" gyre systems (curved arrows).

2. Evaluation of model forecasts with observations

We have evaluated model forecasts during DYNAM from the ECMWF and GFS models. The results are summarized in Kerns and Chen (2013b). Main points include: 1) predictive skill decreases with time (2-3 days forecasts are much better than 10-15 days), and 2) synoptic-mesoscale variability and air-sea coupling may be important for global models. Figure 2 shows an example of ECMWF precipitation forecast compared with TRMM satellite observation.

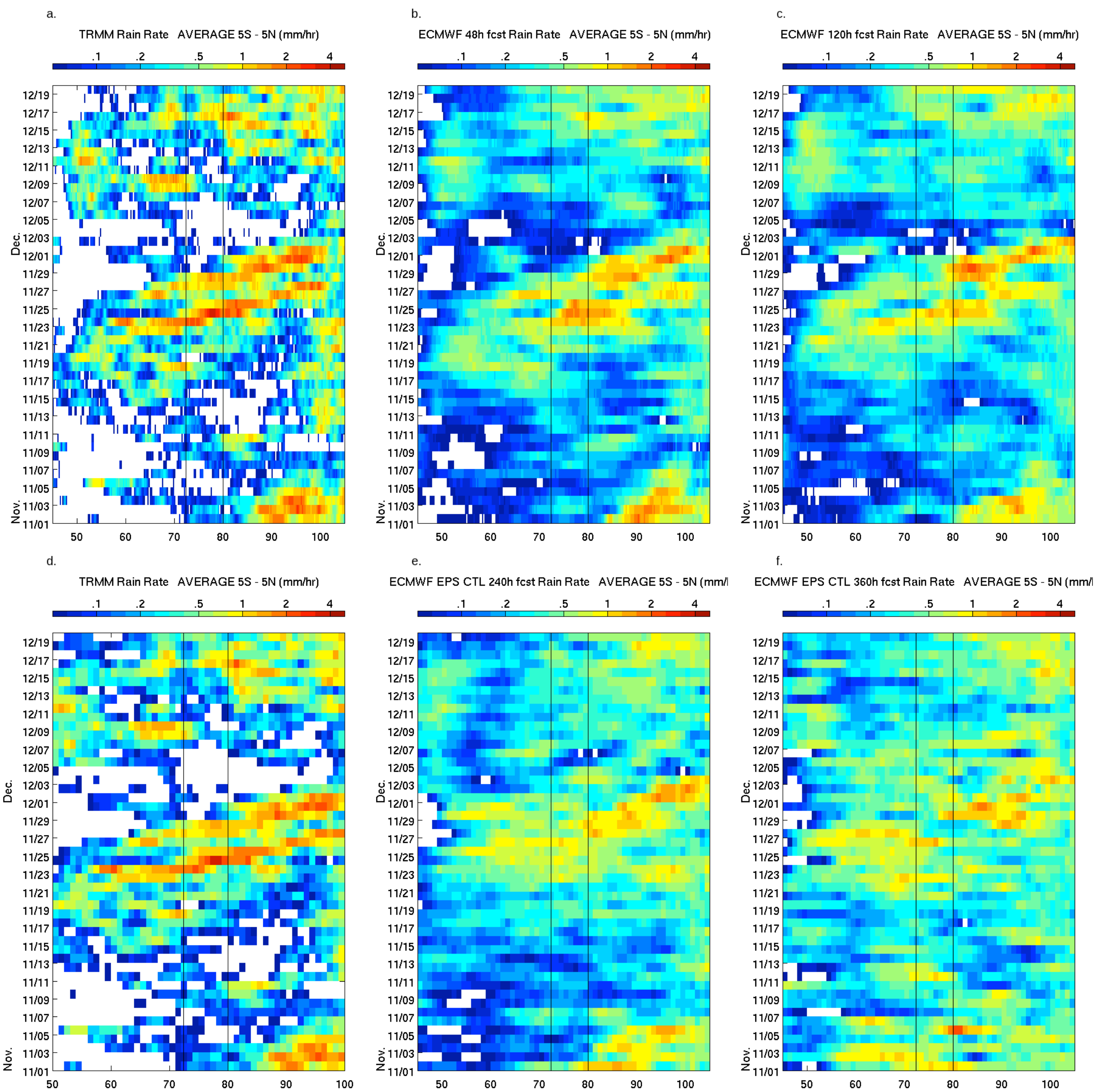

Figure 2. TRMM rainfall and rainfall forecasts from the ECMWF forecast system. (a) and (d) are the TRMM data degraded to 0.25 deg., 24 h (1.0 deg., 24 h) resolution. (b) and (c) are for the 48-hour (120-hour) ECMWF forecasts at the same valid times as the TRMM data. (e) and (f) are for the 240-hour (360-hour) forecasts of the ECMWF-ctl at the same valid times as the analysis. All fields are averaged from 5^0S to 5^0N.

3. Comparison of aircraft and ship-based observation of air-sea fluxes

To better understand and evaluate the air-sea fluxes using the aircraft GPS dropsonde and ABXT data, we have compared the sensible heat and latent heat fluxes with the data from *R/V Revelle* during the DYNAM leg 3 that is overlapped in time with the NOAA P-3 observations in November-December 2011 (Fig. 3). It shows the two data sets are in very good agreement overall.

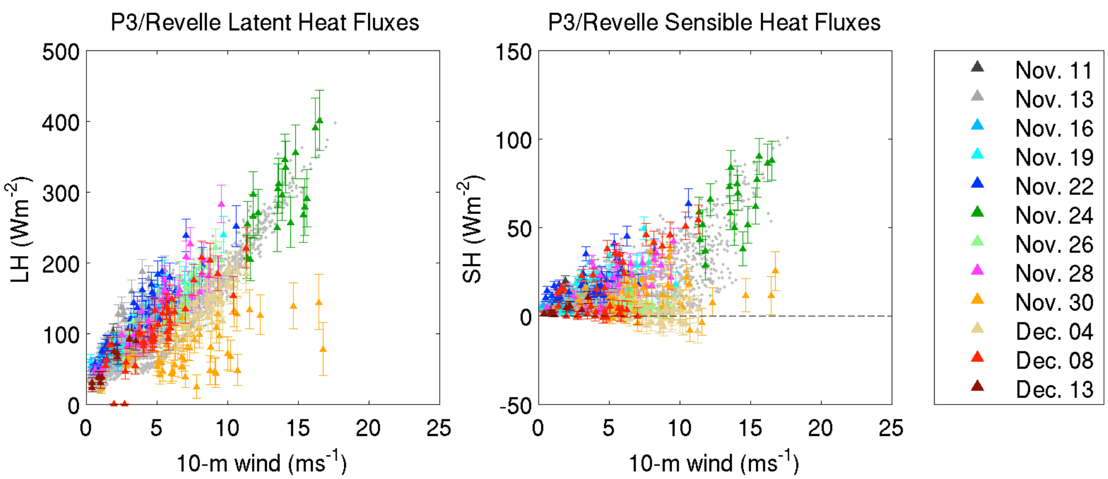

Figure 3. Air-sea surface latent (left) and sensible (right) heat fluxes observations from the NOAA P-3 aircraft GPS dropsonde and AXBT data (color-coded by dates) and from the ship-based data (grey dots) from R/V Revelle (courtesy of Dr. Jim Edson). The error bar for the aircraft data is estimated using +/- 0.5 SST uncertainty.

4. Convective cold pools and boundary layer recovery

To characterize the convective cloud systems and their impact on the air-sea interface, we use the aircraft data to investigate both the convectively generated cold pool structure and boundary layer recovery time during convectively active and suppressed phases of MJO. The P3 Doppler radar data is first used to identify the convective cloud and precipitation structures. The dropsonde data are used to compute the negative bouncy depth. The boundary layer recovery time is then calculated based on the method used in TOGA COARE (Jorgensen et al. 1997). The air-sea fluxes are computed from the dropsonde and AXBT data. Preliminary results show that the depth of the cold pools is related to the environmental water vapor (700-500 hPa layer mean) and the boundary layer recovery times are positively correlated with the surface wind speed and air-sea fluxes (Fig. 4). The drier environment during the suppressed phase seems to produce deeper cold pools and slower recovery time. Stronger winds and increased air-sea fluxes reduce the recovery time during the convectively active phase, which indicate a positive feedback between the convection and air-sea fluxes.

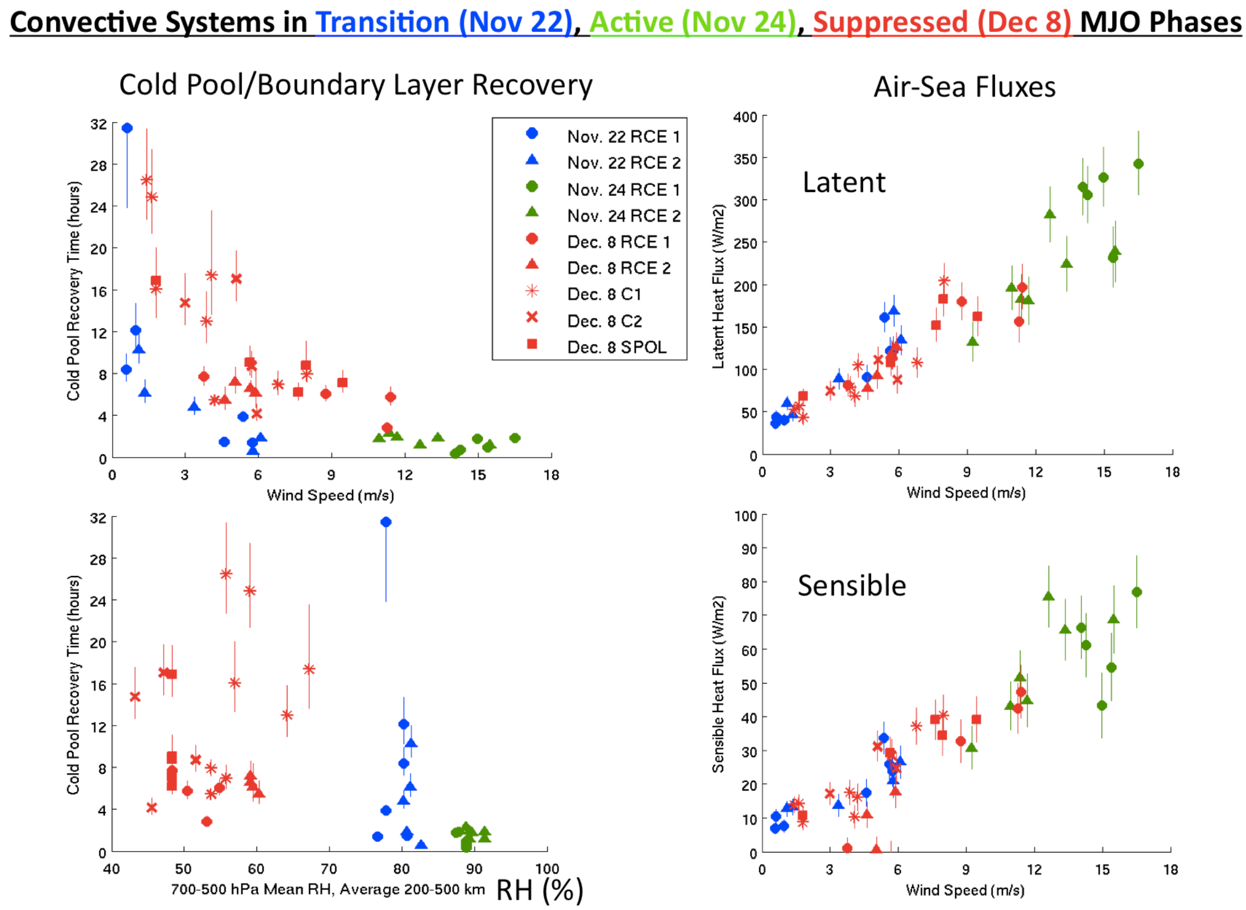

Figure 4. Convectively generated cold pools and boundary layer recovery times are computed from convective flight modules (RCEs) during MJO transition phase (Nov 22, 2011), convective active phase (Nov 24), and convectively suppressed phase (Dec 8): (a) boundary layer recovery time varying with wind speed, (b) cold pool (negative buoyancy) depth varying with 700-500 hPa mean RH, (c) latent and (d) sensible heat fluxes varying with wind speed. The vertical bars represent uncertainty using +/- 1.0 ^{o}C in SST variations.

FY14 WORK PLAN

The UM group will complete the following tasks: 1) continue to finish the satellite and aircraft data analysis of convective cloud systems, air-sea fluxes, and cold pool structure and recovery, 2) completing the science results in peer reviewed publications, and 3) working with NRL COAMPS team to process and analyze the COAMPS model output in the same way as the DYNAMO observations.

PUBLICATIONS

Kerns, B. W., and S. S. Chen, 2013a: Equatorial dry air Intrusion and related synoptic variability in MJO initiation during DYNAMO, *Mon. Wea. Rev*., accepted with revisions.

Kerns, B. W., and S. S. Chen, 2013b: ECMWF and GFS model forecast verification during DYNAMO: Multi-scale variability in MJO initiation over the equatorial Indian Ocean , *J. Geophys. Res.*, in review.

Judt, F., and S. S. Chen, 2013: A “convective cxplosion” and its environmental conditions in MJO initiation observed during DYNAMO , *J. Geophys. Res.*, submitted.

Chen, S. S., B. W. Kerns, D. P. Jorgensen, N. Guy, C.-Y. Lee, F. Judt,J. Delanoë, N. Viltard, E. Fontaine, and C. Zappa, 2013a: Overview of Aircraft Observations during DYNAMO: Emerging science in MJO, *Bull. American Meteor. Soc.*, to be submitted in November.

Chen, S. S., A. Saravin, B. W. Kerns, D. P. Jorgensen, 2013b: Air-sea coupling in MJO: Convective cold pool structure and recovery, *J. Atmos. Sci.*, to be submitted in November 2013.